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Mayer

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[54] **OIL SEPARATOR FOR REFRIGERATION APPARATUS**

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[51] **Int. Cl.**[5] **F25B 43/02**

[52] **U.S. Cl.** **62/470**; 62/84; 62/193

[58] **Field of Search** .... 62/470, 193, 468, 84; 210/168; 55/421, 423, 459 R, 323, 482, 321

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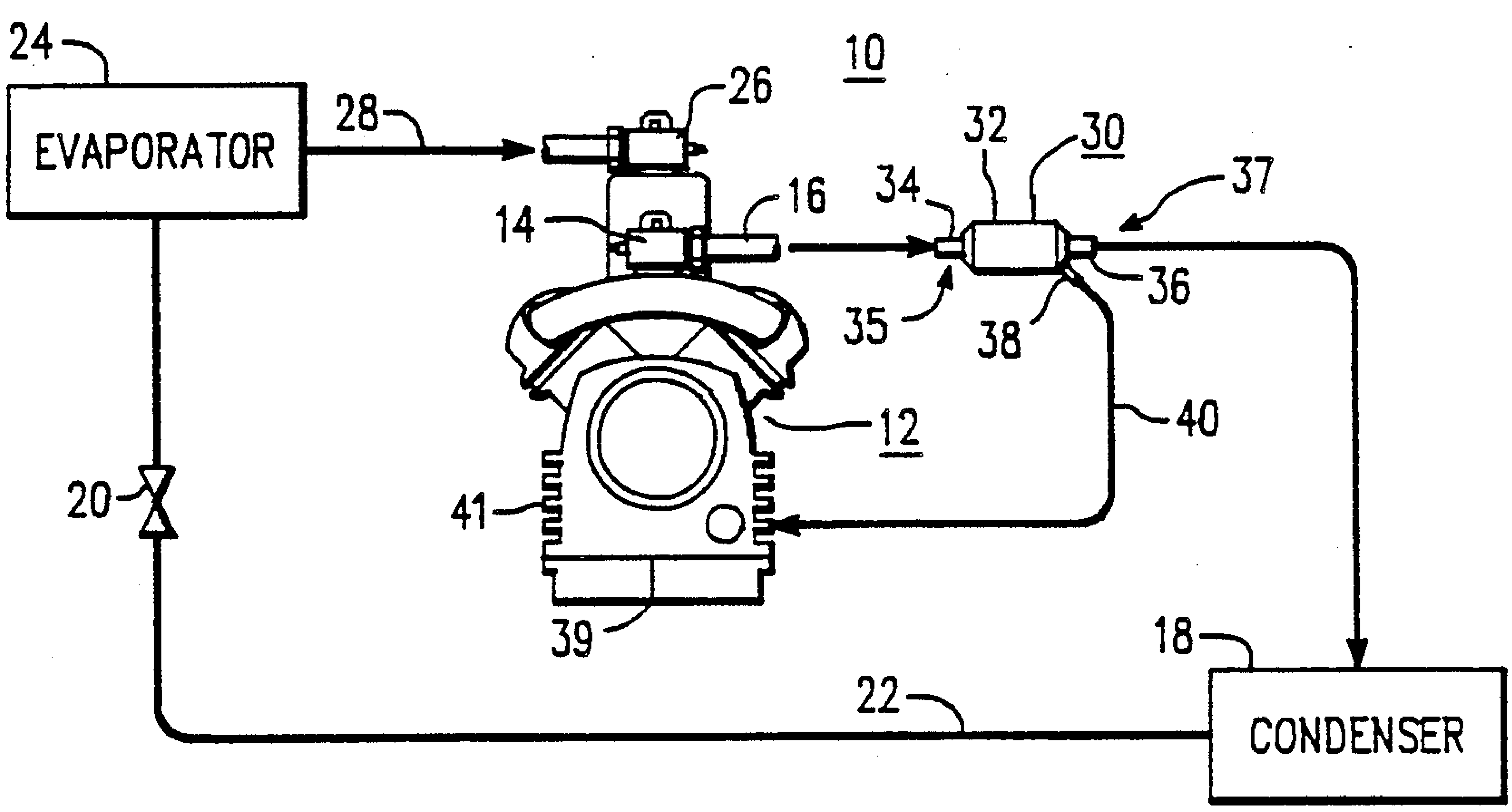
[57] **ABSTRACT**

An oil separator suitable for separating oil from vaporized refrigerant leaving the high pressure discharge side of a refrigerant compressor, and for returning the separated oil to the compressor crankcase. The oil separator includes an elongated housing having a longitudinal axis. Oil separation stages and a capillary tube are disposed within the housing. The capillary tube has a first end into which oil may flow, and a second end in fluid flow communication with an oil return outlet on the housing. The first end of the capillary tube and the oil return outlet are positioned relative to one another such that the longitudinal axis of the housing may be oriented at any selected angle in a range of ninety degrees between horizontal and vertical orientations. The capillary tube has a bore and length selected such that a predetermined refrigerant flow rate is created which carries oil to the crankcase.

9 Claims, 4 Drawing Sheets



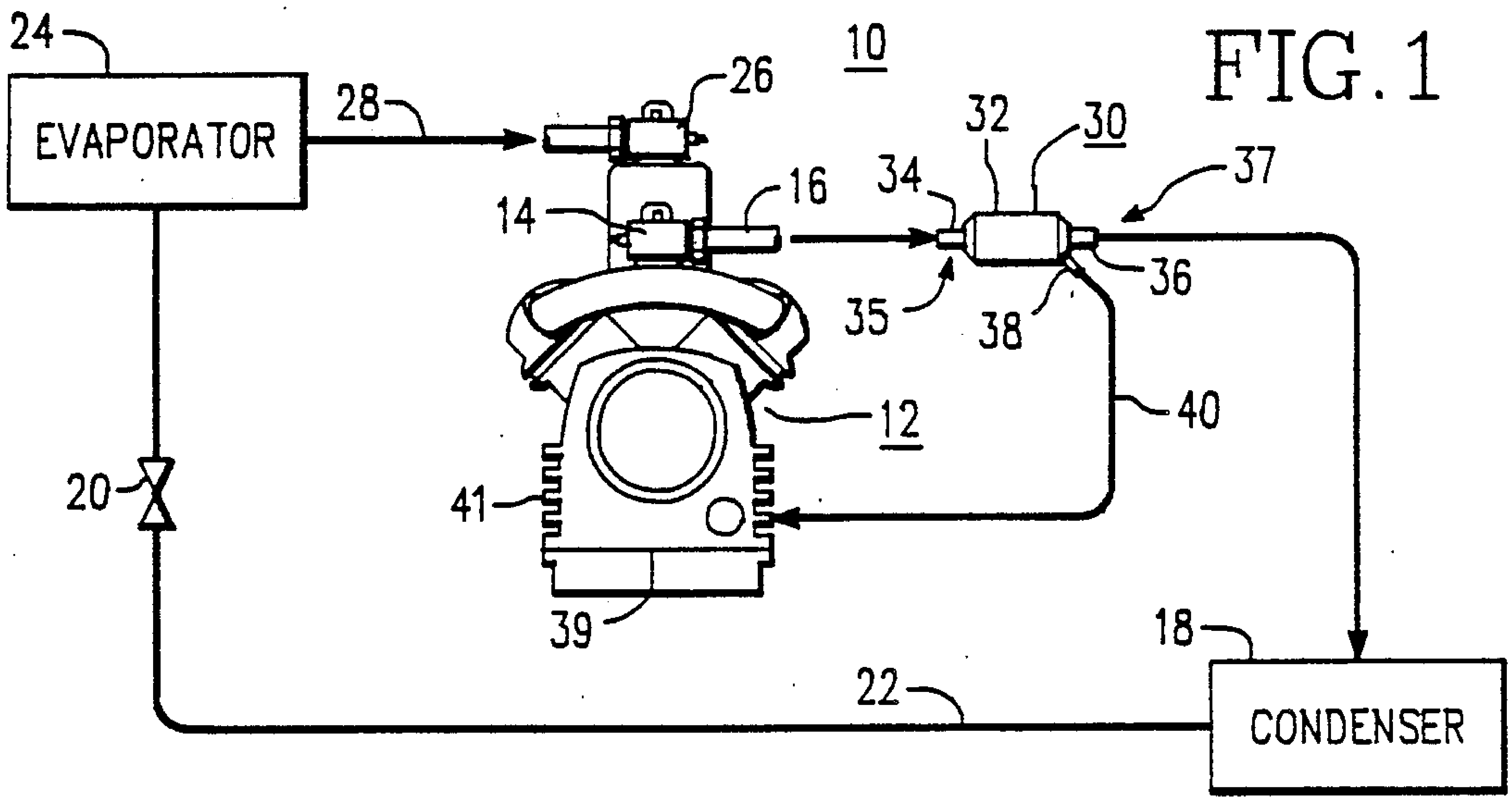


FIG. 1

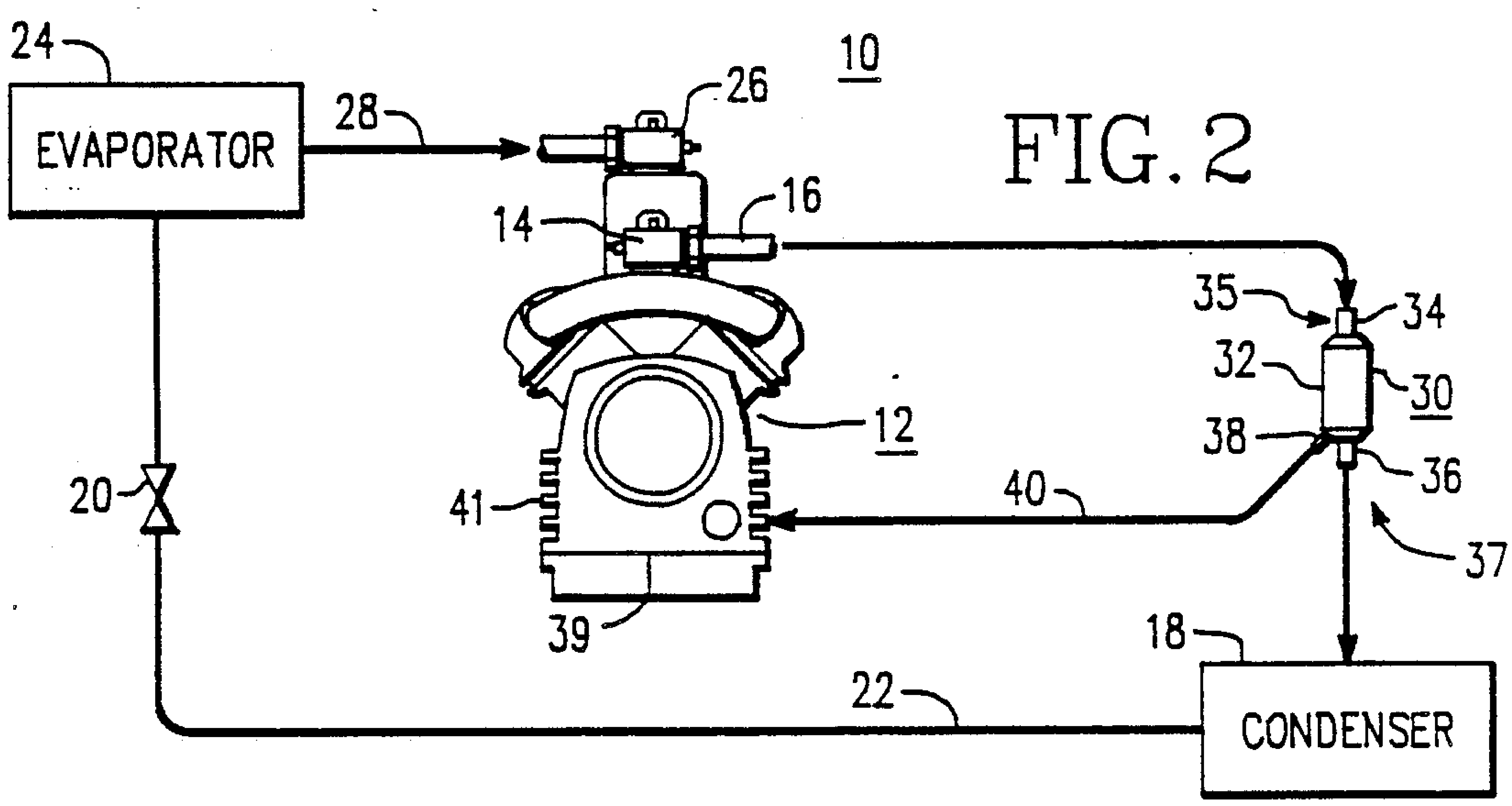


FIG. 2

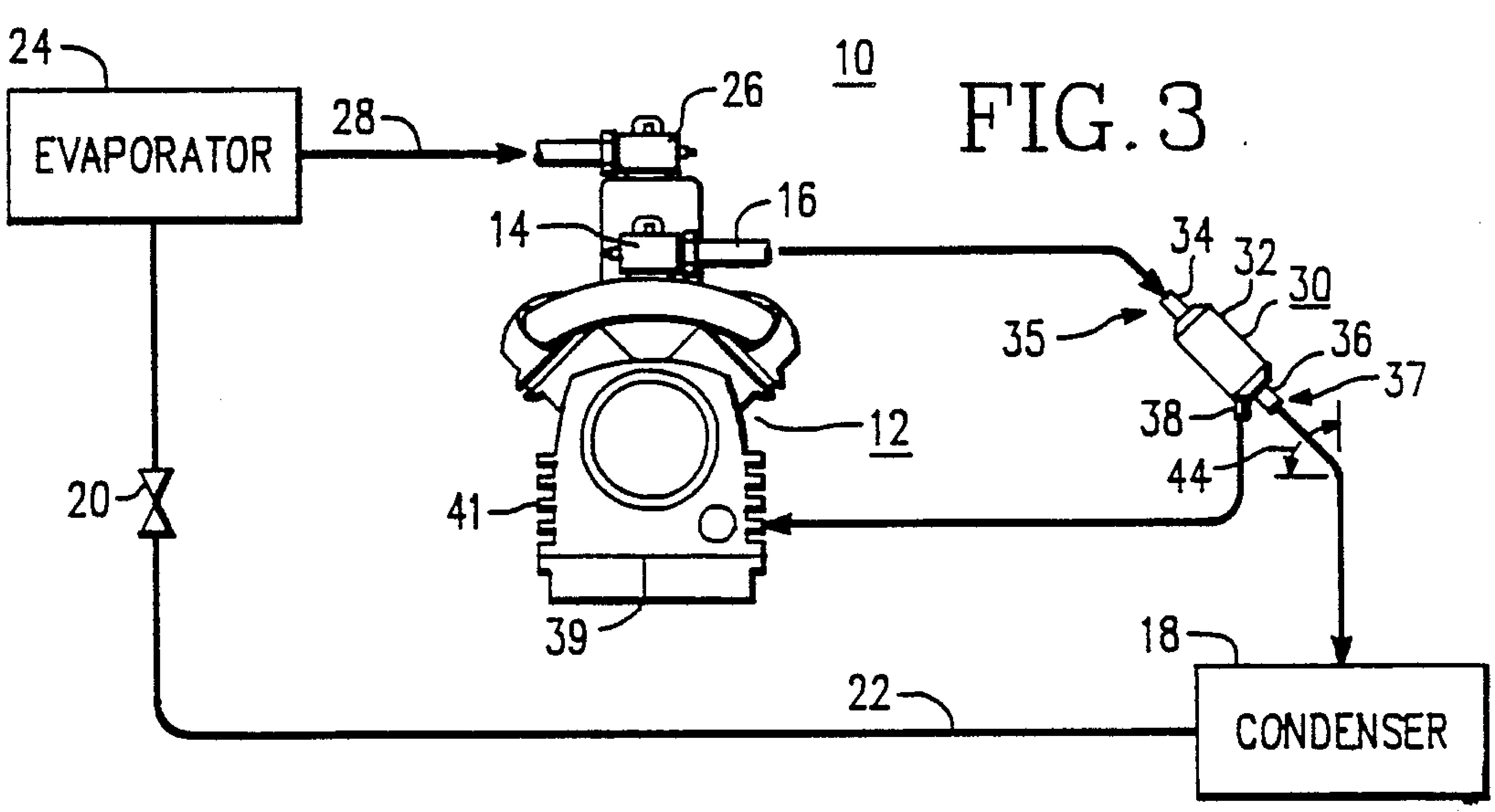
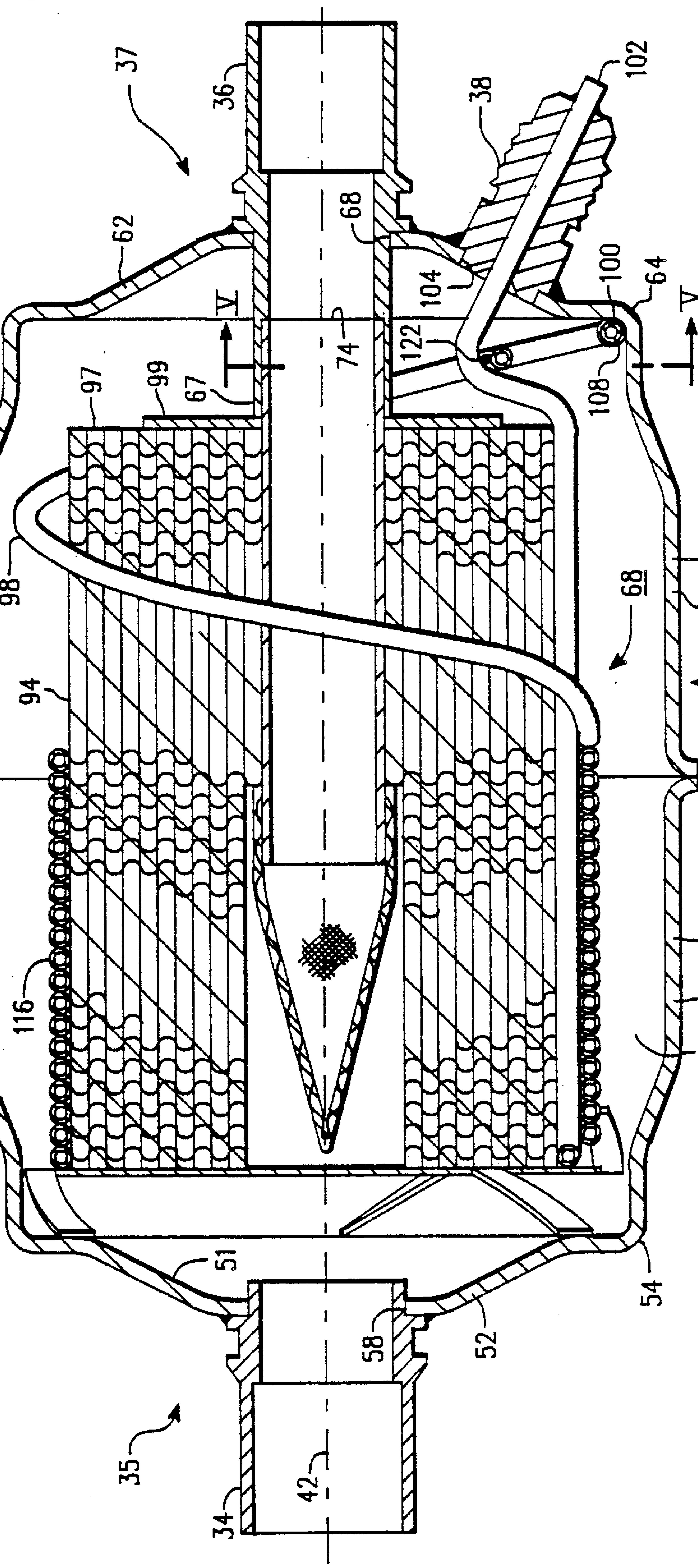


FIG. 3

FIG. 4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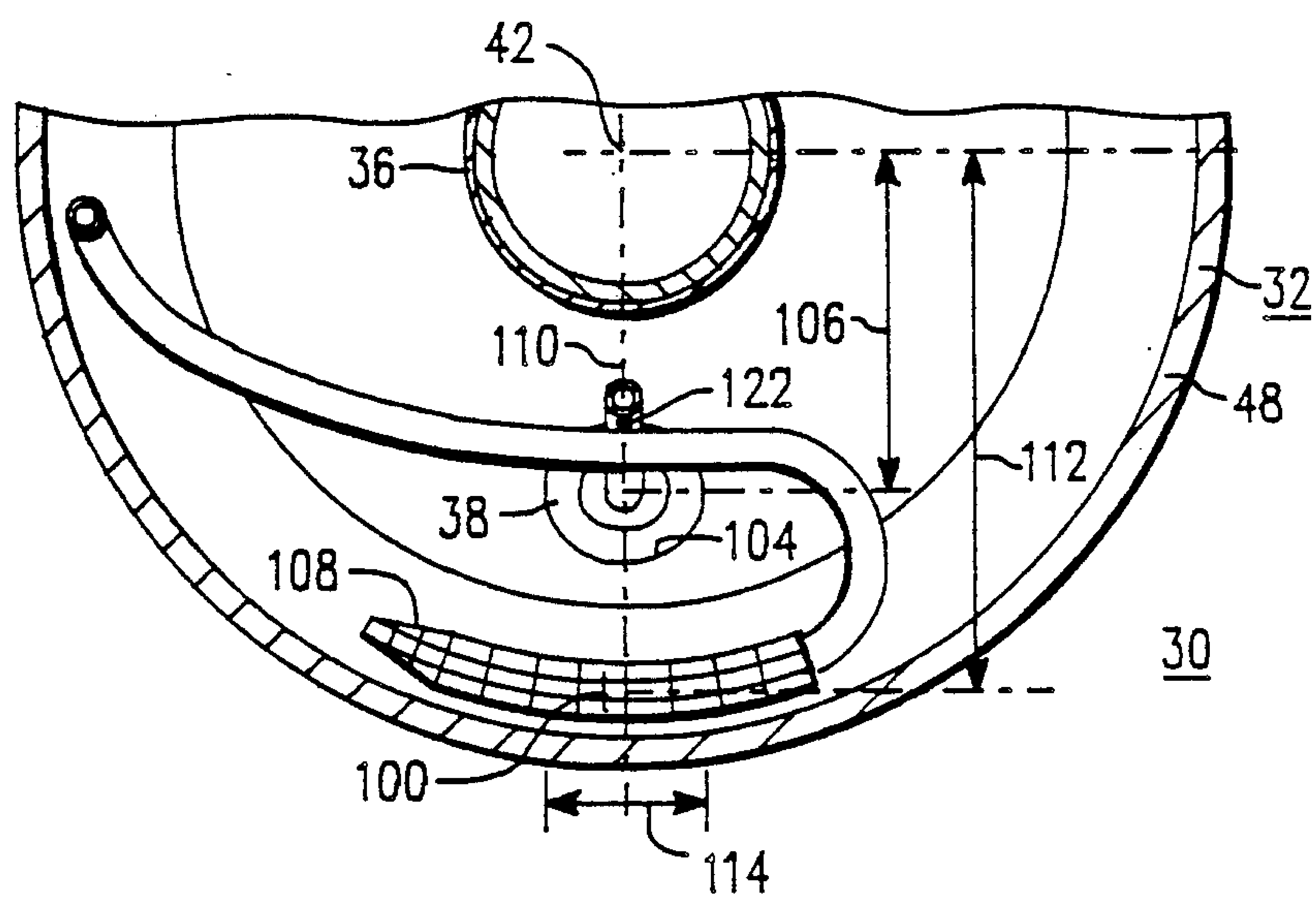

FIG. 5

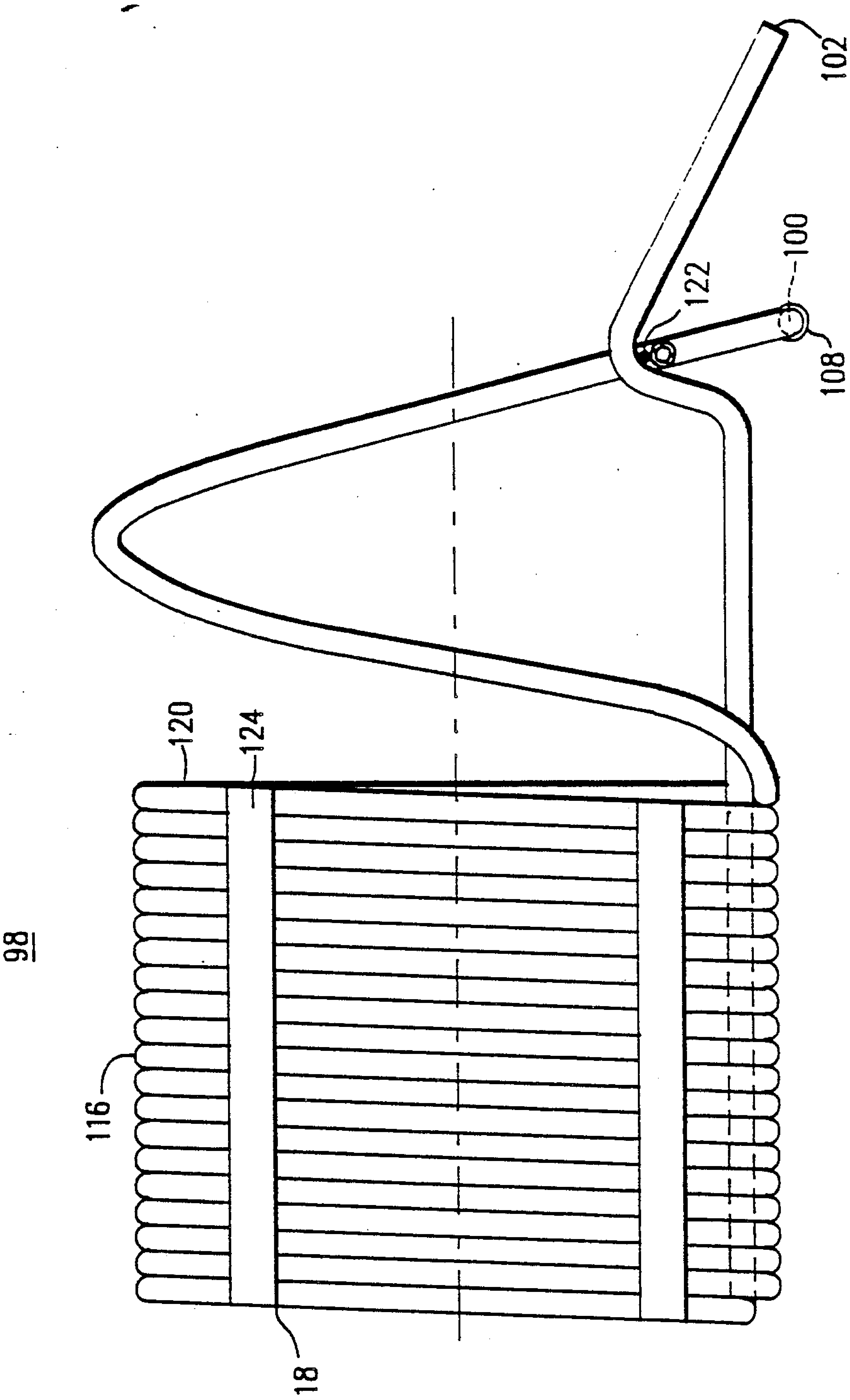

FIG. 7

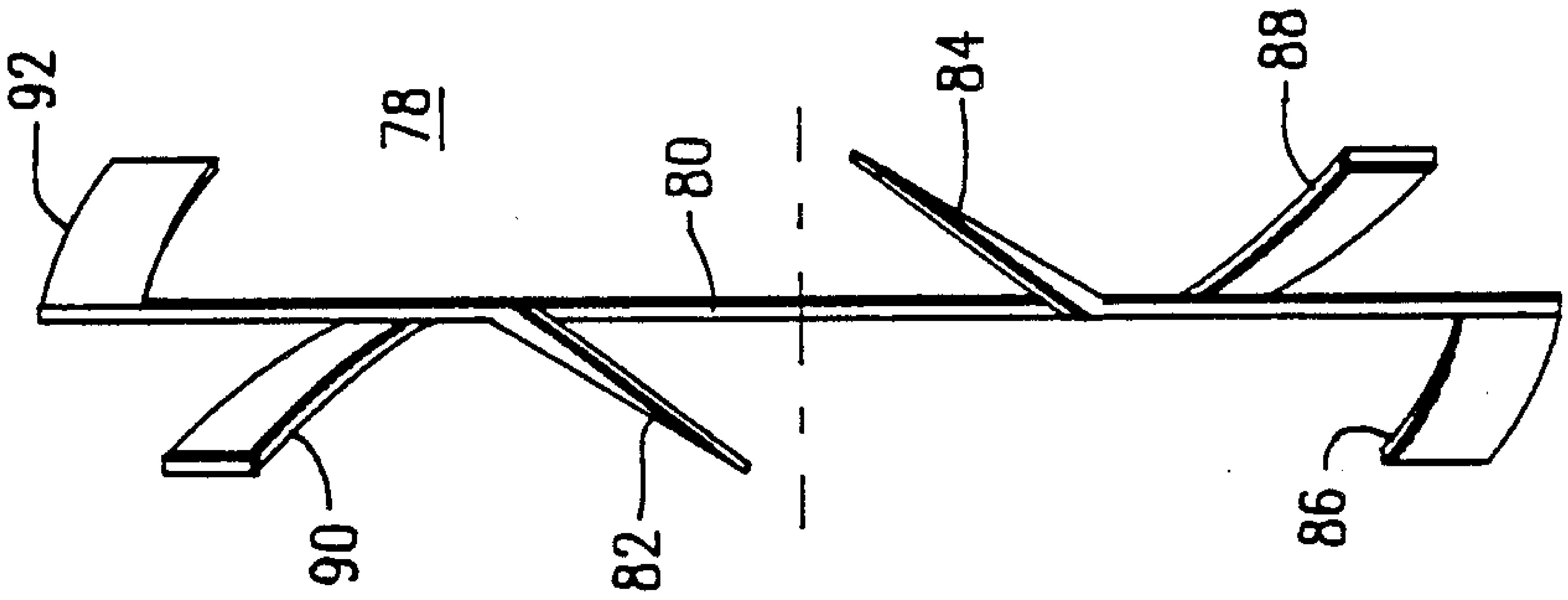

FIG. 6

OIL SEPARATOR FOR REFRIGERATION APPARATUS

TECHNICAL FIELD

The invention relates in general to oil separators, and more specifically to oil separators suitable for removing oil from vaporized high pressure refrigerant being discharged from a refrigerant compressor, and returning the oil to a low pressure oil sump in the compressor crankcase.

BACKGROUND ART

Oil separators are used in refrigeration systems to remove the compressor lubricating oil aerosol from the hot, high pressure compressor discharge refrigerant vapor, e.g., R-12, R-22, R-502, and to return this oil to the compressor oil sump, which is essentially at suction pressure. This function benefits the compressor during periods of marginal lubrication. This function also improves the cooling effectiveness of the entire refrigeration system, as this oil/refrigerant aerosol would normally penalize the refrigeration system by diminished heat transfer through the condenser and evaporator coils, and by reduced compressor volumetric efficiency from diminished refrigerant mass flow rate. The oil separator prevents these functional problems by intercepting this compressor oil before it can circulate through the refrigeration system, and returning it directly back to the oil sump.

There are two general classes of refrigeration oil separators, classified by their different methods of pressure reduction, whereby oil removed from the high pressure side of the compressor is returned to the low pressure oil sump. One type uses a ball-float valve to meter oil flow from an oil separator reservoir. This type of oil separator is vulnerable to mechanical vibration and shock, and is thus more appropriate for static or fixed refrigeration systems. The other class of oil separators uses a restrictive orifice, such as a capillary tube, to return the oil to the low pressure sump. This type is not affected by vibration and shock, and may be used in transport refrigeration systems, for example.

Oil separators for smaller capacity refrigeration systems, such as transport refrigeration systems used for cooling the cargoes of trucks, trailers, and containers, are relatively costly, they have marginal performance effectiveness, and they require vertical axis installation. The orientation limitation is due to the fact that the capillary oil-return tube depends upon gravity to return the separated oil. The vertical axis orientation limitation can present awkward installation difficulties, particularly in many truck refrigeration applications with very confined access space.

Thus, it would be desirable and it is an object of the invention to provide a new and improved oil separator suitable for high vibration and shock environments, which is relatively inexpensive, is highly effective without excessive pressure drop, and which does not require vertical axis mounting.

SUMMARY OF THE INVENTION

Briefly, the present invention is a new and improved oil separator suitable for use in refrigeration systems which operate in environments where shock and vibration are present, such as in transport refrigeration systems. The oil separator includes an elongated housing defining an enclosed space having first and second axial ends, and a longitudinal axis which extends between the ends. A refrigerant inlet and a refrigerant outlet are disposed at the first and second axial ends, respectively, and an oil return outlet is disposed at the second end, radially spaced from the longitudinal axis by a first predetermined dimension.

In a preferred embodiment of the invention, oil is removed from the incoming refrigerant vapor in two successive stages, a centrifugal stage and a coalescing filter stage. The oil collects within the housing via gravity.

A capillary tube having first and second ends is disposed within the enclosed space. The second end of the capillary tube is in fluid flow communication with the oil return outlet. The first end of the capillary tube is also disposed at the second axial end of the enclosed space. The first end is radially spaced from the longitudinal axis in substantially the same direction as the oil return outlet, with the radial spacing exceeding the first predetermined dimension. This location of the first end of the capillary tube places it in fluid flow relation with the gravity fed supply of collecting oil when the longitudinal axis of the housing is substantially horizontal and the housing is oriented about its axis such that the first end of the capillary tube is vertically below the oil return outlet.

The first end of the capillary tube will remain in fluid flow communication with the gravity fed supply of separated oil when the longitudinal axis of the housing is vertically oriented, and also at any selected angle between the horizontal orientation and the vertical orientation, as long as the first end of the capillary tube is below the oil return outlet.

The length and bore of the capillary tube are selected to provide a predetermined refrigerant flow rate from the first end to the second end, providing the motive force for returning oil removed from the refrigerant back to the compressor oil sump. The refrigerant flow rate through the capillary tube is selected to be a very small portion of the total refrigerant flow rate through the oil separator, and it thus has little affect on the refrigeration capacity of the associated refrigeration system.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will become more apparent by reading the following detailed description in conjunction with the drawings which are shown by way of example only, wherein:

FIG. **1** is a partially schematic and partially diagrammatic representation of a refrigeration system showing horizontal mounting of an oil separator constructed according to the teachings of the invention;

FIG. **2** is similar to FIG. **1**, except showing the oil separator of the invention vertically mounted;

FIG. **3** is similar to FIG. **1**, except illustrating that the oil separator may be mounted at any selected angle between the horizontal and vertical mounting orientations of FIGS. **1** and **2**;

FIG. **4** is a cross sectional view of the oil separator shown in FIGS. **1**, **2** and **3**, illustrating a preferred embodiment of the oil separator;

FIG. **5** is a cross sectional view of the oil separator shown in FIG. **4**, taken between and in the direction of arrows V—V in FIG. **4**;

FIG. 6 is a side elevational view of an inlet louver shown in section in FIG. 4, which louver is part of a first stage of oil removal; and

FIG. 7 is a side elevational view of a capillary tube shown in section in FIG. 4, which returns a gravity fed supply of lubricating oil removed from refrigerant vapor to the oil sump of an associated refrigerant compressor.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to the drawings, and to FIGS. **1**, **2** and **3** in particular, there is shown a refrigeration system **10**, such as a transport refrigeration system, or any other type of refrigeration system which may operate in an environment which includes shock and vibration. Refrigeration system **10** includes a refrigerant compressor **12** which discharges hot, high pressure refrigerant vapor from a discharge port and service valve **14** to a hot gas line **16**. A condenser **18** removes heat from the refrigerant, condenses it to a high pressure liquid, and supplies the refrigerant to an expansion valve **20** via a liquid line **22**. The resulting lower pressure liquid refrigerant is vaporized in an evaporator **24**, removing heat from air surrounding the evaporator coil, and the vaporized refrigerant is returned to a suction port and service valve **26** via a suction line **28**.

An oil separator **30** constructed according to the teachings of the invention is disposed in the hot gas line **16**. Oil separator **30** includes an elongated housing **32** having a refrigerant inlet **34** at a first axial end **35** which receives refrigerant vapor and entrained lubricating oil aerosol from the compressor **12**, and a refrigerant outlet **36** at the remaining or second axial end **37** which discharges refrigerant vapor minus the oil aerosol for continued travel through the refrigeration system **10**. An oil return outlet **38** returns separated lubricating oil to an oil sump **39** in the crankcase **41** of compressor **12** via an oil return line **40**.

FIG. **1** illustrates that oil separator **30** may be mounted with a longitudinal axis **42**, shown in FIG. **4**, which extends between the first and second axial ends **35** and **37**, substantially horizontally oriented. FIG. **2** illustrates that oil separator **30** may be mounted with the longitudinal axis **42** substantially vertically oriented. FIG. **3** illustrates that oil separator **30** may be mounted with longitudinal axis **42** mounted at any desired angle in a range **44** of substantially ninety degrees between the horizontal orientation of FIG. **1** and the vertical orientation of FIG. **2**.

FIG. **4** is a cross sectional view of oil separator **30**, illustrating a preferred embodiment of the invention. Housing **32** is preferably formed of first and second similar metallic shells **46** and **48**, such as **15** gage cold rolled steel, which cooperatively define a closed space **49** having first and second axial ends **51** and **53**, respectively. Shell **46** includes a cylindrical tubular portion **50** which is joined near the first end **35** of the housing **32** by an end wall portion **52**, which may be integral with cylindrical portion **50**, to form a corner portion **54**. Cylindrical portion **50** is open and outwardly flanged at the remaining end, as indicated at **56**. End wall portion **52** includes a central opening **58** concentric with longitudinal axis **42** which receives the refrigerant inlet connector **34**. The refrigerant inlet connector **34**, which may also be formed of steel, is welded or brazed to end wall portion **52** of housing shell **46**.

In like manner, shell **48** includes a cylindrical tubular portion **50** which is joined near the second end **37** of the housing **32** by an end wall portion **62**, which may be integral with cylindrical portion **60**, to form a corner portion **64**. Cylindrical portion **60** is open and outwardly flanged at the remaining end, as indicated at **66**. End wall portion **62** includes a central opening **68** concentric with longitudinal axis **42** which receives the refrigerant outlet connector **36**. The refrigerant outlet connector **36**, which may also be formed of steel, is welded or brazed to end wall portion **62** of housing shell **48**.

Refrigerant outlet connector **36** includes an end portion **67** within the hollow space defined by the second shell **48**, to which an oil separating assembly **68** is attached. For example, oil separating assembly **68** may include a hollow tubular metallic support member **70**, which also functions as an outlet tube for the refrigerant after the oil has been removed therefrom. Tubular member **70**, which may be formed of steel, includes first and second ends **72** and **74**, respectively. The first end **72** includes a screen or filter member **73**, such as a fine mesh tubular screen having one closed end, and an open end. The open end surrounds and is suitably attached to tubular member **70** adjacent to end **72** for preventing particulate matter from entering the associated refrigeration system **10** via tubular member **70**. Tubular member **70** is dimensioned near its second end **74**, and refrigerant outlet connector **36** is dimensioned adjacent its end **67**, to form a tight telescoping press fit or brazed joint between them. The first and second shells **46** and **48** may then be joined together at their flanges **56** and **66**, such as by welding.

For purposes which will become apparent as the description proceeds, the oil separating assembly **68** has a cylindrical outer form defining an outer diameter which is less than the inside diameter of cylindrical portions **50** and **60**, to define an annular space **72** between the oil removing assembly **68** and the inner walls of cylindrical portions **50** and **60**.

In a preferred embodiment of the invention, the oil separating assembly **68** includes first and second successive stages of oil removal, with the first stage including an inlet louver **78**, best shown in the side elevational view of FIG. **6**. Inlet louver **78** is a round, flat metallic plate, such as galvanized steel, having a plurality of evenly spaced vanes formed therein adjacent the outer periphery of the plate, which vanes are alternately bent outward from the main flat plate body portion **80** in opposite directions. For example, six vanes **82**, **84**, **86**, **88**, **90** and **92** may extend outwardly from body portion **80**, with vanes **82**, **86** and **90** extending outwardly in uniformly spaced circumferential relation from one side of body portion **80**, and with vanes **84**, **88** and **92** extending outwardly in uniformly spaced circumferential relation from the other side of body portion **80**.

The inlet louver **78** is positioned within the space defined by housing **32**, adjacent to the first axial end **35**, such that the major flat sides thereof are perpendicular to the longitudinal axis **42**. Vanes **82**, **84**, **86**, **88**, **90** and **92** are aligned with the annular space **76**. The hot high pressure refrigerant vapor with entrained lubricating oil aerosol strikes the inlet louver **78** and the vanes **82**, **84**, **86**, **88**, **90** and **92** direct the refrigerant vapor into a helical vortex flow into and around the annular space **76**. The centrifugal force field generated in the free vortex that results from the inlet louver's vanes causes the entrained oil droplets to migrate toward and impinge against the inside walls of the housing **32**. This forms an oil film on the inside walls of housing shells **46** and **48** that flows by gravity to accumulate on the lowest portion of the inner walls defined by shells **46** and **48**.

The second stage of oil separation occurs in a coalescent filter pack **94** which has a first axial end **95** which starts at and is in contact with the inlet louver **78**, a second axial end **97** which is positioned by a large metallic washer member **99**, and a central opening **101**. The second axial end **97** is in spaced relation relative to the end wall **62** at the second axial end **37** of the housing **32**. The coalescent filter pack **94** receives the refrigerant vapor after the initial centrifugal oil separation has occurred, and the partially "cleaned" stream of refrigerant then flows back through the filter pack **94**, where it enters the screened end **72** of outlet tube and support member **70**. The screened end **72** is axially spaced from the inlet louver **78** to provide a refrigerant entry space **96**. The screen **73** on the first end **72** of outlet tube and support **70** prevents any fragments from the filter pack **94**, or similar debris, from leaving the oil separator outlet **36** and contaminating the refrigeration system **10**.

The residual oil aerosol still in the refrigerant as the refrigerant enters filter pack **94** coalesces on the strands of the filter pack **94**. In a preferred embodiment of the filter pack **94**, it is in the form of a porous cylindrical pack of knitted wire mesh, such as .005 inch diameter galvanized steel wire. A flattened and crimped "stocking" of such knitted wire mesh is coiled into a resilient spool or cylinder about the tubular support and outlet member **70**. While galvanized wire is preferred in an environment of mechanical shock and vibration, other alternative materials for the filter pack **94** include spun fiberglass and expanded open-cell foam. The filter pack **94** functions by intercepting the microscopic oil mist particles in the gas stream, which causes the oil to coalesce or agglomerate into larger drops which migrate by gravity along the wire strands to the bottom of the pack, where the oil falls by gravity to the interior bottom of housing **32**. The drops of oil become too large to become re-entrained in the stream of refrigerant vapor as the coalesced drops of oil migrate through the pack and fall to the bottom of the enclosed space.

Before assembly, the axial length of the coalescent filter pack **94** is somewhat longer than the available assembled distance between the flat surface of body portion **80** of louver **78** and the metal support disc **99** which is concentric with outlet tube **70** and axially positioned by refrigerant outlet **36** at its end **67**. The axial compression resilience of the coalescent filter pack **94** which extends axially somewhat beyond the first axial end **118** of capillary coil **116** before assembling, provides a spring-like pressure which causes the coalescent filter pack **94** to bear against the inlet louver **78** and hold louver **78** against axial end **52** of shell **46**. This is the desired assembled position of louver **78**, and it automatically assumes this desired position when shells **46** and **48** are pressed and welded together at flanges **56** and **66**.

The refrigerant vapor may be prevented from entering the filter pack **94** too soon by enclosing the filter pack for at least about one-half of its axial length, starting at its first axial end **95** adjacent to the inlet louver **78**, to shield inlet space **96** and prevent a "short-circuiting" of the refrigerant vapor through the end of the filter pack **94** which directly surrounds space **96**. This enclosure about the first axial end of the filter pack may take the form of a thin walled tubular metallic skirt formed of any suitable material, such as aluminum or steel, but in a preferred embodiment of the invention, the shielding effect is provided by the configuration of a capillary tube **98** which provides an oil pick-up and return function, eliminating the need for a separate shielding skirt.

The refrigerant vapor, with the major portion of the compressor lubricating oil removed, thus enters the screened end **72** of the output tube **70**, where it continues to the condenser **18**. The refrigerant vapor within oil separator **30** is at the relatively high discharge compressor pressure, and the accumulated oil on the "bottom" of the housing **32** must flow from this relatively high pressure region to the compressor oil sump, which is essentially at compressor suction pressure. This pressure reduction is accomplished in the oil return circuit by the hereinbefore mentioned capillary tube **98**.

The bore diameter and length of the capillary tube **98** are selected to provide a flow of compressor discharge vapor back to the compressor oil sump at a very low rate, such as approximately one to five percent of the total compressor flow. This flow of refrigerant vapor serves as the vehicle to carry the separated oil back to the compressor, without a significant reduction or waste of compressor capacity. An annealed copper tube having an outside diameter of .094 inch, an inside diameter of .049 inch, and a length of about 142 inches has been found to be suitable, but other materials, lengths and bore diameters may be used.

The capillary tube **98** has first and second ends **100** and **102**, respectively, with the first end being located at the corner **64** between tubular portion **60** and end wall **62**, and with the second end being in fluid flow communication with or through the oil return outlet **38**. The oil return outlet **38** is mounted in an opening **104** formed in end wall **62**, which opening is radially spaced from the longitudinal axis **42** by a first dimension **106**, best shown in FIG. **5**, which is a cross-sectional view of oil separator **30** taken between arrows V—V in FIG. **4**. The first end **100** of capillary tube **98** is surrounded by a strainer, screen or filter member **108**, best shown in FIG. **5**, and, as also shown in FIG. **5**, end **100** is radially spaced from the longitudinal axis **42** in the same direction as opening **104** and by a second dimension **112** which exceeds the first dimension **106**. End **100** thus lies substantially on a plane **110** which is common with longitudinal axis **42** and the center of opening **104**. The dimension **114** in FIG. **5** indicates that end **100** may lie anywhere within this dimension relative to plane **110**, which is approximately .5 inch on either side of plane **110**. The strainer **108** may be fine-mesh tubular screen which is fastened to the capillary inlet end **100** to prevent stray particulate matter from possibly plugging the small bore of the capillary tube **98**. An equivalent strainer function may also be provided with a sintered pressed powdered metal filter, or the like.

Between the first and second ends **100** and **102**, as shown in FIGS. **4** and **7**, capillary tube **98** is rolled into a closely spaced cylindrical coil **116** having first and second axial ends **118** and **120**, respectively. A plurality of axially disposed, circumferentially spaced solder beads **124** hold the closely spaced turns of cylindrical coil **116** together to form a rigid cylinder. Coil **116** has an inside diameter which is slightly smaller than the outside diameter of the filter pack **94**, providing additional compression of the resilient filter pack **94**. The axial length of the cylindrical coil **116** is at least equal to about one-half of the axial length of filter pack **94**, with the first axial end **118** starting at the inlet louver **78** to form a shield about the space **96** adjacent the entry end **72** of the tubular outlet tube **70**. Thus, refrigerant vapor entering the annular space **76** is forced to flow towards the second axial end **97** of the filter pack **94**, ensuring a substantially uniform flow of refrigerant vapor through the entire filter pack **94**, instead of being concentrated heavily at the first axial end **95**.

The strategic positioning of the oil entry end **100** of the capillary tube at the corner **64** of the housing **32** where the housing **32** changes from a cylindrical configuration defined by wall portion **60** to enter end wall **62**, may be ensured by tack soldering two portions of the capillary tube **98** together, as indicated at **122**, at a location close to both ends **100** and **102** of the capillary tube **98**. Since end **102** is fixed to outlet **38**, such as by extending completely through outlet **38**, as illustrated, soldering two portions of capillary tube **98** together adjacent to their ends **100** and **102** will fix the location of the first end **100** and its associated filter **108**. This eliminates the need for a separate clip to hold the desired position of end **100**.

The relative locations of the oil entry end **100** of the capillary tube **98**, plus the orienting of the inlet end **100** in substantially the same plane **110** as the longitudinal axis **42** and the center of opening **104**, enables the capillary tube inlet **100** to "see" the gravity fed supply of collected compressor lubricating oil with a horizontal orientation of longitudinal axis **42**, with a vertical orientation, and with any angle therebetween.

When the axis **42** is vertically oriented, it does not make any difference how the oil separator **30** is circumferentially oriented about axis **42**. When axis **42** is horizontally oriented, the oil separator should be circumferentially oriented such that end **100** is at the very bottom of housing **32**. As the angle of orientation is raised from horizontal towards the vertical, end **100** should retain this "bottom" position. In other words, when viewing end **100** in FIG. **4**, end **100** may be thought of as a pivot axis, with the oil separator **30** being pivoted clockwise about this pivot axis, to reach the desired angle between horizontal and vertical. This orientation flexibility of oil separator **30** is particularly advantageous when used with refrigeration systems having cramped mounting locations, such as in the engine compartment under the hood of certain vehicles.

I claim:

1. An oil separator, suitable for fluid flow communication with the high pressure discharge side of a refrigerant compressor having an oil sump which operates at suction pressure, for separating oil from high pressure refrigerant and returning it to the lower pressure oil sump, comprising:

an elongated housing defining an enclosed space having first and second axial ends, a longitudinal axis which extends between said first and second axial ends, a refrigerant inlet at said first axial end, and a refrigerant outlet at said second axial end,

an oil return outlet at the second axial end, spaced radially outward from the longitudinal axis by a first predetermined dimension,

means in said enclosed space for separating oil from the refrigerant, such that said separated oil accumulates by gravity within the enclosed space,

a capillary tube in the enclosed space having first and second ends,

the first end of said capillary tube being disposed at the second axial end of the enclosed space, spaced radially outward from the longitudinal axis by a second predetermined dimension which is greater than said first predetermined dimension, and in substantially the same direction from the longitudinal axis as the oil return outlet, such that the first end of the capillary tube lies in a plane common with the longitudinal axis and the oil return outlet,

the second end of said capillary tube being in fluid flow communication with said oil return outlet,

said capillary tube having a bore and length selected to provide a predetermined refrigerant flow rate through the capillary tube, from the first to the second end thereof, when the refrigerant inlet is connected to receive high pressure refrigerant, and the oil return outlet is connected to the oil sump, with said predetermined flow rate carrying oil adjacent to the first end of said capillary tube back to the oil sump,

whereby the first end of the capillary tube may be maintained at substantially the lowest point of the enclosed space when the housing is mounted with said longitudinal axis at any selected angle in a substantially ninety degree range between horizontal and vertical.

2. The oil separator of claim **1** wherein the means in the enclosed space for separating oil from refrigerant includes successive first and second stages of oil separation, with the second stage creating an annular space between the housing and second stage, and with the first stage including means for directing refrigerant entering the enclosed space into a helical vortex flow around the annular space.

3. The oil separator of claim **2** wherein the second stage includes a coalescing filter.

4. The oil separator of claim **1** wherein the means in the enclosed space for separating oil from refrigerant includes successive first and second stages of oil separation, with the second stage including a coalescing filter having first and second axial ends near the first and second axial ends of the enclosed space, respectively, and a central opening which extends between said first and second axial ends,

said coalescing filter being dimensioned to create an annular space between the housing and filter,

said first stage including means for directing refrigerant entering the enclosed space into a helical vortex flow around the annular space,

and including refrigerant flow directing means for causing the refrigerant to flow through the coalescing filter from the second axial end towards the first axial end.

5. The oil separator of claim **4** wherein the flow directing means includes a tubular member disposed within the central opening of the coalescing filter such that entry to the tubular member may be gained only near the first axial end of the coalescing filter,

and wherein the capillary tube includes a portion in the form of a cylindrical coil having closely spaced turns disposed about the coalescent filter, with said cylindrical coil portion being disposed to cause refrigerant to enter the coalescing filter near the second axial end of the filter.

6. The oil separator of claim **5** wherein the tubular member disposed within the central opening of the coalescing filter has first and second axial ends, and including a screen member attached to the first axial end to prevent particulate matter from entering the tubular member, and with the second axial end being in fluid flow communication with the refrigerant outlet.

7. The oil separator of claim 1 including a screen member disposed to prevent particulate matter from entering the first end of the capillary tube.

8. The oil separator of claim 1 wherein the second end of the capillary tube is fixed to the oil return outlet, and including means fixing a predetermined location of the capillary tube near the first end thereof to a predetermined location of the capillary tube near the oil return outlet.

9. The oil separator of claim 1 wherein the means in the enclosed space for separating oil from refrigerant includes successive first and second stages of oil separation, with the first stage being a louver member which directs refrigerant entering the enclosed space via the refrigerant inlet into a helical vortex flow, and the second stage includes a resilient, compressed coalescing filter pack, with the compressed filter pack providing a spring pressure against said louver member which holds the louver member in a desired assembled position relative to the first axial end of the enclosed space.

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